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SHITE 270 C A JOHNSON BLDG

DENVER 2 COLORADO

AD 667357

INITIAL FLUID INJECTION CHARACTERISTICS
PRE-CAMBRIAN INTERVAL
PRESSURE INJECTION DISPOSAL WELL
ROCKY MOUNTAIN ARSENAL
DENVER, COLORADO

Prepared for
Department of the Army
U. S. Army Engineer District, Omaha
Corps of Engineers

APR 4 1280

cen approve

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Signed and Sealed

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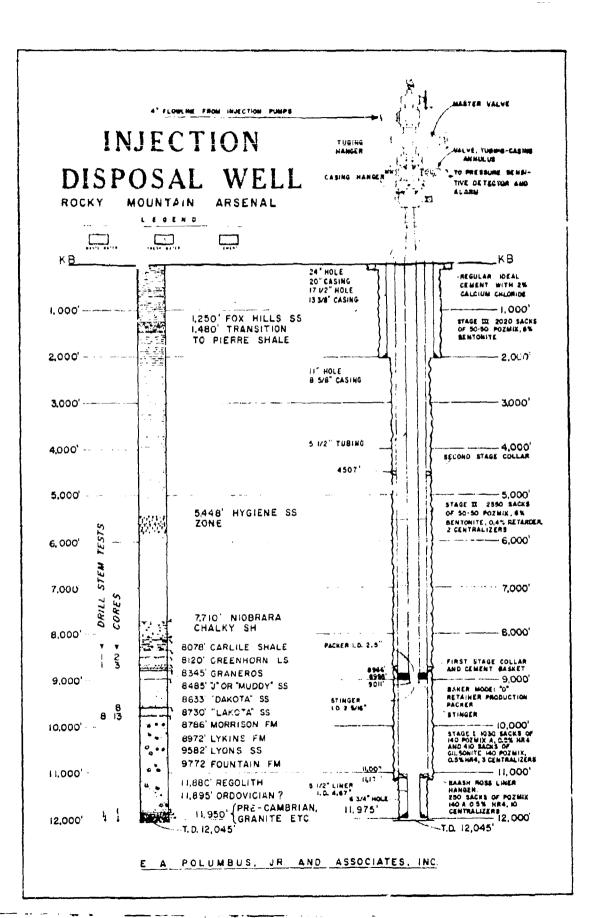


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INTRODUCTION

The accumulating waste effluent from chemical plants at the Rocky Mountain Arsenal, Denver, Colorado presented the problem of finding a permanent solution for disposal in such a manner as to protect shallow fresh water aquifers from contamination. The Chemical Corps of the United States Army considered various methods for handling these waste fluids and decided upon the drilling of a deep pressure injection disposal well in the search for a subsurface formation reservoir capable of accepting fluid at rates up to 800 gallons per minute under a maximum of 2,000 psi surface injection pressure for a number of years.

The site selected for the well on the Arsenal grounds was near storage Pond F in Section 26. Township 2 South, Range 67 West, Adams County, Colorado. The responsibility for designing and drilling the well was vested in the Department of the Army, U. S. Army Engineer District, Omaha, Corps of Engineers. The petroleum engineering consulting firm of E. A. Polumbus, Jr., and Associates, Inc., was engaged to design the drilling program, manage the drilling and testing, provide engineering and geological services, and conduct the initial injection tests.

Reference to the following two reports prepared by Polumbus and Associates will provide adequate background details concerning the design . and drilling of the injection well:

"Final Design Analysis, Pressure Injection Disposal Well, Rocky Mountain Arsenal (July 5, 1960)"

"Final Report on Drilling, Rocky Mountain Arsenal Pressure Injection Disposal Well (November 30, 1961)"

The latter report presents the drilling history and details of the formation evaluation program followed in the disposal well which was spudded March 10, 1961 and penetrated into Pre-Cambrian granite to a final total depth of 12,045 feet.

Prior to drilling the injection well eight zones were considered to offer potentialities as injection reservoirs. These consisted of the Hygiene, Codel, "J", Dakota, and Lakota sandstones, the Morrison, Lyons and Fountain formations. Two of these now appear to offer potential injection reservoirs; namely, fractured intervals of the Lyons and Fountain formations. Additionally, the Pre-Cambrian granite hornblende gneiss (Figure 3) containing fractures within the interval 11,975 to 12,045 feet constituted an initially unsuspected potential injection reservoir. The core No. 28 (Table 14), drill stem test Nos. 13 and 14 (Tables 1 and 2 and Figure 2), and the behavior of lost circulation encountered while penetrating this section indicated a zone of sufficient merit to warrant completing the well with 5 1/2-inch liner cemented at 11,975 feet (Figure 1) and proceeding first to evaluate this open hole interval for an injection reservoir.

This report, "Initial Fluid Injection Characteristics, Pre-Cambrian Interval, Rocky Mountain Arsenal Pressure Injection Disposal Well,"

constitutes a sequel to the Final Report on Drilling. It presents the results of initial injection tests using City of Denver potable water to evaluate the Pre-Cambrian interval 11,975 feet to total depth 12,045 feet for an injection reservoir.

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OBJECTIVES OF INITIAL INJECTION TESTS

Predictions of injection performance may be made on zones of interest by conducting drill stem tests as drilling proceeds and without the necessity of completing the well. From the results of these tests, decisions may be made whether or not to conduct further tests. In the Rocky Mountain Arsenal Disposal well, every effort was extended to thoroughly examine promising zones whenever conditions were permissible. Such a zone exists in the Pre-Cambrian interval 11,975 to 12,045 feet wherein the fractured granite encountered caused considerable drilling fluid to be lost to the formation.

Before attempts are made to inject disposal fluid into a formation, it is prudent first to examine various reservoir parameters which will be useful in diagnosing problems that may arise during continuous injection operations. The important parameters are as follows:

- 1. Reservoir capacity to accept fluid.
- 2. Drainage radius.
- 3. Total reservoir pore volume.
- 4. Reservoir pressure and temperature.
- 5. Well damage or skin effect.
- Compatibility of injection fluid with reservoir fluid and matrix material.

Numerous techniques may be employed in evaluating these properties, all of which were utilized in the Rocky Mountain Arsenal well whenever conditions permitted.

■4年 F A FOLUMBUS S AN AS OFFATE (N Ordinary means of volumetric computations are impractical for two important reasons. First, horizontal limits of the reservoir are unknown. Second, fracture porosity evidently accounts for a substantial portion of the total void space. The results of the tests conducted to date give strong evidence that the "effective" reservoir is expanding as injection continues, but it is impractical to attempt to identify the drainage radius or effective reservoir volume, because the necessary parameters cannot be accurately defined at this time.

Additional injection tests with potable water are considered unnecessary, and injection of treated Pond F water is now recommended.

It is advisable to continue to conduct periodic pressure fall-off tests as
proposed herein for the purpose of better defining the parameters mentioned above.

Included in the testing program was a determination of friction factors of the tubing string under various flowing rates. These factors are required in subsequent calculations of reservoir performance where pressure losses due to friction are significant.

RESULTS OF INITIAL INJECTION TESTS

Injection tests included in the study incorporate considerations of mud losses into the formation while drilling and completing, brief injection tests with potable water through 4 1/2-inch drill pipe while the rig was on location and injection tests with City of Denver water through 5 1/2-inch tubing using surface plant pumping facilities. The results of all tests are shown graphically in Figure 12, which relates rates of injection to wellhead injection pressures. It may be noted that in the reservoir conditions that existed during the time of these initial injection tests, a definite relationship exists which can be extrapolated to indicate an injection rate of 800 gallons per minute at a wellhead pressure of approximately 865 psig.

The chronology of test; conducted on the initial injection interval is presented graphically in Fig. 4. Details of individual tests are presented graphically in Figures 5, ,, and 8 to 11. In Figure 4, values of reservoir pressure and cumulative differential volume injected or removed from the formation are plotted as a function of time. The summary of calculations of important pressure tests are also included in this figure. It may be pointed out that the results of each test were evaluated and utilized in making a decision on subsequent test procedures. Because of the complex nature of the Pre-Cambrian interval tested, dependable results were not always obtainable.

Introduced into the equations from which calculation of injectivity characteristics were made are certain physical constants for which measured values are unobtainable. In such cases, it was necessary to use assumed values for expediency in completing the calculations. It is believed that computations for all parameters are reasonable except possibly drainage radius. Nevertheless, calculations of drainage radius are significant in that it appears to be increasing with volume injected. This feature is not entirely unexpected in view of the prevailing fracture system, and it may very well prove to be a valuable asset in fulfilling the initial objectives of the disposal well.

The values of various physical constants used in evaluating pressure tests are as follows:

Datum depth (Zd)	12,000	ft
Temperature at 12,000 ft (Tf)	240	oF
Viscosity of water at 240°F (//)	0.28	ср
Compressibility of water (Cw)	3×10^{-7}	psi
Effective compressibility (Cw _e)	8.8×10^{-6}	psi
Porosity (Fractures only) (ϕ)	3.0	%
Density formation water (/ fw)	1.05	gm/cc
Density fresh water (Pw)	1.00	gm/cc
Density drilling fluid (p_m)	1.08	gm/cc
Density muddy water (/2mw)	1.06	gm/cc

The tabulation of results of each pressure test conducted in this interval are included in Tables 1 through 12 excluding Table 8. The

calculated values of important parameters for all tests are summarized in Table 13. In addition to the symbols given previously, the following definitions of symbols apply to Table 13.

△V Barrels fluid injected or withdrawn.

 $\sum \triangle V$ Cumulative differential volume.

Fluid Fluid in hole during pressure test.

fluid Density of fluid.

Zt Position of pressure bomb.

Zd-Zb Distance between bomb depth and datum.

 $\triangle P_{cor}$ Pressure correction = 0.433 (\nearrow fluid) ($Z_d - Z_b$).

P Static pressure at 12,000 ft.

P* Extrapolated pressure at 12,000 ft.

P Maximum or minimum pressure at 12,000 ft.

Kh Formation capacity in millidarcy-feet.

F.E. Flowing efficiency (accounts for well damage)

re Apparent drainage radius in ft.

An attempt was made to secure a representative formation fluid sample in order to determine compatibility and other characteristics of this fluid. Because of the loss of drilling fluid into the fractures during drilling and coring, it was very questionable whether either drill stem test No. 13 or 14 provided uncontaminated formation fluid samples. The best sample analyzed indicated a chloride content of 46, 400 ppm.

Normally it is possible to produce a well for a short time to clean out the contaminated fluid and then secure a bottom-hole sample which should very nearly reflect true formation fluid characteristics. Initial

injection tests through the drill pipe, while the rig was still on location, indicated that the interval below 11,975 feet would accept fluid at sufficient rates to warrant further investigation. Before the drilling rig was moved efforts were made to obtain a formation fluid sample through 4 1/2 inch drill pipe by air lift which is a high capacity lifting method. This proved to be uneconomical because of the low rate of fluid entry. Upon removal of the rig from the location, rods, tubing and pump were run as a more economical means of obtaining the desired sample. Figure 7 presents graphically the chloride content of the produced fluid as a function of cumulative volume withdrawn.

After several days of pumping the well pumped down, and the recovery became so small that continuance of the effort to gain a representative sample was unwarranted. It should be noted that after producing 1,100 barrels fluid in excess of the injected volume, the chloride content was considerably lower than that obtained from the drill stem test No. 14. The significance of this behavior is that either a limited reservoir volume is implied, or during production the fractures possibly were being squeezed together by compression forces which resulted in restricting fluid entry into the wellbore. This factor supports the suggestion given above that the effective reservoir is expanding when the pressure is restored by injection and may continue to do so during the continuous injection period to follow. The composite graph (Figure 12) showing

injection rates versus injection pressures for all injection tests in the Pre-Cambrian interval 11,975 feet to 12,045 feet lends support to this interpretation.

CONCLUSIONS

- 1. The rates, with corresponding injection pressures at which the PreCambrian interval (11,975 to 12,045 feet) accepted fluid during tests,
 are shown graphically on Figure 12. Extrapolation of the rate vs.

 pressure trend indicates an injection pressure of approximately 865
 psig at an injection rate of 800 gallons per minute. The maximum
 actual injection rate through 5 1/2-inch tubing with available surface
 plant facilities was 400 gallons per minute at 650 psig wellhead pressure with no observed pressure rise during test.
- The reservoir consists of fractures which apparently expand as additional volumes of fluid are injected.
- Extension of effective reservoir boundaries is indicated for the period of testing discussed herein.
- 4. Continued injection of fluid and the contemporaneous recording of pressure and injected volume data, plus periodic pressure fall-off tests are essential to a more positive evaluation of the Pre-Cambrian reservoir.

RECOMMENDATIONS CONCERNING THE CONTINUOUS INJECTION PERIOD

- It is recommended that the following data be collected for each day
 of injection operations.
 - a. Injection Hate
 - b. Daily Injected Volume
 - c. Tubing Pressure
 - d. Annulus Pressure
 - e. Solids content and chemical characteristics of injected fluid
- 2. Periodic observations of tubing pressure should be made throughout the day during the initial injection period. Significant increases should be studied without delay as related to reservoir performance. If the tubing pressure reaches 2,000 psi, the injection rate should be reduced.
- 3. During the first 90 days of operation, a 24-hour fall-off test is recommended at the end of each 30-day period. Every effort should be exercised to maintain a constant injection rate for approximately 10 days prior to shutting in the well for these tests.
- 4. Future test requirements should be evaluated after examining the results of the 30-day fall-off tests.
- 5. A water storage pressure chamber should be connected to the 8 5/8-ingh 5 1/2-inch annulus to provide for variations in the annular volume requirements due to subsurface temperature variations as influenced by well operations.

near the wellhead as possible in order to evaluate the severity of corrosion in the water injection path. Some oilfield operators consider the upper limit of corrosive activity to be 1.0 MPY (0.001 inches per year) for subsurface conditions. This however requires individual economic analysis involving casing design specifications, cost of replacement, cost of corrosion inhibition, possible irreparable reservoir damage due to the end products of corrosion, and damage to the permanent installation in the wellbore.

It should be mentioned that coupons do not necessarily evaluate the entire injection path. Before extensive or costly corrosion inhibition programs are initiated based upon coupon tests alone, additional corroboration should be obtained from other sources; such as caliper surveys in the 5 1/2-inch tubing, periodic visual inspection of the casing head, pumps and other surface appurtenances.

ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL DRILL STEM TEST NO. 13

September 5, 1961

Time Minutes	Shut-in Pressure, psi At 9,645 Feet	Time Minutes	Shut-in Pressure, pei At 9,645 Feet	
o	2, 565	50	3, 732	
1	2,981	54	3, 732	
2	3, 111	58	3, 732	
3	3,211	62	3, 732	
4	3,274	66	3, 732	
5	3, 335	70	3, 732	
6	3,393	74	3, 732	
7	3, 436	78	3, 732	
8	3, 477	82	3, 732	
9	3,515	86	3, 732	
10	3,548	90	3, 732	
14	3,634	94	3, 732	
18	3,673	98	3, 732	
22	3,692	102	3, 732	
26	3, 703	106	3, 732	
30	3, 712	110	3, 732	
34	3, 719	114	3, 732	
38	3,727	118	3, 732	
42	3, 727	122	3, 732	
46	3, 732		J, 136	

Formation
Interval Tested
Flow Periods
Closed-in Times
Gauge Depth
Initial Flow Pressure
Initial Shut-in Pressure
Final Flow Pressure
Final Shut-in Pressure
Recovery

Early Paleozoic

9,660-11,985

3 and 60 minutes

30 and 122 minutes

9,645

856-1,117

3,868

925-2,565

3,732

5,330 feet mud (no water cushion)

ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL DRILL STEM TEST NO. 14

September é, 1961

Time Minutes	Shut-in Pressure, psi At 11,007 Feet
0	3,508
9.3	3, 782
18.6	3,910
27.9	4,000
37.2	5, 059
46.5	4,093
55.8	4, 116
65.1	4. 129
74.4	4, 138
83.7	4.148
93.0	4, 155

Formation
Interval Tested
Flow Periods
Closed-in Times
Gauge Depth
Initial Flow Pressure
Initial Shut-in Pressure
Final Flow Pressure
Final Shut-in Pressure
Recovery

Early Paleozoic
11,020-11,985
6 and 156 minutes
none and 93 minutes
11,007 feet
1,684-1,844
none (bypassed and reopened)
1,692-3,508
5,155
2,000 feet water cushion
5,400 feet salt water

TEST NO. I (September 20, 1961)

Time	Surface Pressure	Pressure at 11,975' K.B.	Remarks
0 min45 min.	975 psi	6170 psi	Injected 16, 200 gallons at 385 GPM.
45 min 0 sec.	850	6045	Instantaneous shut-in pressure.
45 min10 sec.	825	602u	Shut-in 10 sec.
45 min20 sec.	525	5720	Shut-in 20 sec.
45 min 30 sec.	250	5445	Shut-in 30 sec.
45 min40 sec.	225	5 20	Shut-in 40 sec.
45 min50 sec.	220	5415	Shut-in 50 sec.
45 min60 sec.	210	5405	Shut-in 60 sec.
46 min 10 sec.	205	5400	Shut-in 70 sec.
46 min40 sec.	190	5385	Shut-in 100 sec.
47 min 10 sec.	175	5370	Shut-in 130 sec.
47 min40 sec.	125	5320	Shut-in 160 sec.
48 min 10 sec.	125	5320	Shut-in 190 sec.
48 min40 sec.	110	5305	Shut-in 220 sec.
49 min10 sec.	110	5305	Shut-in 250 sec.
53 min 0 sec.	75	5270	Shut-in 480 sec.
56 min 0 sec.	50	5245	Shut-in 660 sec.
58 min 0 sec.	o	5195	Shut-in 780 sec.

Injection test through 10, 700 feet of 4 1/2-inch drill pipe. 5 1/2-inch liner set at 11,975 feet.
Injection interval 11,975-12,045 feet.

TEST NO. II (September 20, 1961)

Time	Surface Pressure	Pressure at 11, 975' K.B.	Remarks
0 min 5 min.	250 psi	5 445 psi	Injected 1008 gallons at 216 GPM
5 min 0 sec.	250	5445	Instantaneous shut-in pressure
5 min, -10 sec.	175	5370	Shut-in 10 sec.
5 min20 sec.	90	5285	Shut-in 20 sec.
5 min 30 sec.	25	5220	Shut-in 30 sec.
5 min40 sec.	O	5195	Shut-in 40 sec.

Injection test through 10, 700 feet of 4 1/2-inch drill pipe. 5 1/3-inch liner set at 11,975 feet.
Injection interval 11,975-12,045 feet.

TEST NO. III (September 29, 1961)

Time	Surface Pressure	Pressure at 11,975' KB	Remarks
0 mia, -15 mia. 15 mia, - 0 sec.	•	6670 psi 6670	Injected 8232 gallons at 538 GPM
15 min10 sec.	225	5420	Instantaneous shut-in pressure Shut-in 10 sec.
15 min20 sec. 15 min30 sec.	-	5420 5405	Shut-in 20 sec. Shut-in 30 sec.
15 min40 sec.	- • -	53 8 5 53 7 0	Shut-in 40 sec. Shut-in 50 sec.
16 min 0 sec.	160	5355	Shut-in 60 sec.
16 min30 sec. 17 min 0 sec.		5305 5295	Shut-in 90 sec. Shut-in 120 sec.
17 min 30 sec. 18 min 0 sec.	80 75	5275 5270	Shut-in 150 sec. Shut-in 180 sec.
18 min 30 sec. 20 min 0 sec.	50 0	5245 5195	Shut-in 210 sec. Shut-in 300 sec.

Injection test through 10, 700 feet of 4 1/2-inch drill pipe. 5 1/2-inch liner set at 11,975 feet. Injection interval 11,975-12,045 feet.

TEST NO. IV (September 20, 1961)

Time, min.	Surface Pressure		Pressure at 11,975' K.B.	Remarks
0-136	700 psi	31 82 ps i	5775 psi	Injected 20,916 at average rate of 250 GPM
137	200			Shut-in 1 min.
146	100	2864	5457	Shut-in 10 min.
156	0	2713	5306	Shut-in 20 min.
176		2652	5445	Shut-in 40 mm.
196		2618	5211	Shut in 60 min.
216		2592	5185	Shut-in 80 min.
236		2577	5170	Shut-in 100 min.
256		2551	5144	Shut-in 120 min.
276		2543	5136	Shut-in 140 min.
296		2524	511 7	Shut-in 160 min.
316		2515	5108	Shut-in 180 min.
33 6		2506	5099	Shut-in 200 min.
356		2498	5091	Shut-in 220 min.
376		2491	5084	Shut-in 240 min.
531		2432	5025	Shut-in 395 min.
546		2432	5025	Shut-in 410 min.
561		2428	5021	Shut-in 425 min.
639		2413	5006	Shut-in 503 min.

Injection test through 10,700 feet of 4 1/2-inch drin pipe. 5 1/2-inch liner set at 11,975 feet.
Injection interval 11,975-12,045 feet.

TEST NO. V (September 20-21, 1961)

Time, min.	Surface Pressurc.ps1	Pressure at 5,000°, psi	Pressure at 11,975', ps	
0	1120	2991	6018	Begin injection at 263 GPM
2	1120	2991	6018	u u
30	1120	2991	6018	11
60	1120	2991	6018	f# +1
120	1120	2991	6018	11
142	1120	2991	6018	Stop injection after 37, 346
				gallons
144		2807	5834	Shut-in 2 min.
152		2783	5810	Shut-in 10 min.
162		2525	5552	Shut-in 20 min.
172		2390	5417	Shut-in 30 min.
182		2287	5314	Shut-in 40 min.
202		2202	5229	Shut-in 60 min.
262		2143	5170	Shut-in 120 min.
322		2116	5143	Shut-in 180 min.
382		2105	5132	Shut-in 240 min.
442		2090	5117	Shut-in 300 min.
502		2084	5111	Shut-in 360 min.
562		2073	5100	Shut-in 420 min.
682		2052	5077	Shut-in 540 min.
802		2027	5054	Shut-in 660 min.

Injection test through 10,700 feet of 4 1/2-inch drill pipe. 5 1/2-inch liner set at 11,975 feet. Injection interval 11,975-12,045 feet.

ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL PRE-CAMBRIAN INTERVAL, 11,975 TO 12,045' CUMULATIVE WATER PRODUCED BY AIR LIFTING AND PUMPING VERSUS CHLORIDE CONTENT OF WATER SAMPLE

Cumulative Production Barrels	Chloride Content	Cumulative Production Barrels	Chloride Content		
650	1,600	4,453	33,500		
2,035	4,000	4, 465	28, 400		
2,090	13,000	4, 483	24,600		
2,517	13,000	4,530	27,000		
2,624	12,000	4,670	26,000		
2,966	15,000	4,699	27,000		
3,330	15,000	4,744	26,000		
3,580	18,000	4, 790	31,000		
3,920	26,000	4,870	32,500		
3,975	25,000	4,896	31,500		
4,011	21,000	4,920	32,000		
4,200	28,000	4,934	31,000		
4,211	32,000	4, 956	33,000		
4,321	29,500	4,982	31, 250		
4,417	33,500	5,001	32,500		

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ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL INJECTIVITY TESTS THROUGH 5 1/2-INCH TUBING PRE-CAMBRIAN INTERVAL 11, 975-12, 045'

TEST NO. 1 January 3, 1962

Shut-in Time	Wellhead Pressure, psi
0	280
10 Seconds	120
20 Seconds	110
30 Seconds	105
40 Seconds	95
50 Seconds	95
60 Seconds	92
2 Minutes	75
3 Minutes	62
4 Minutes	54
5 Minutes	48
6 Minutes	42
7 Minutes	35
8 Minutes	29
9 Minutes	25
10 Minutes	21
11 Minutes	17
12 Minutes	13
13 Minutes	9
14 Minutes	6
15 Minutes	3
16 Minutes	0

Effective Injection Time	856 minutes
Average Injection Rate	206 GPM
Volume of Denver City Water Injected	4, 200 barrels

The bottom-hole pressure was not recorded since the clock in the Amerada pressure bomb malfunctioned.

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ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL INJECTIVITY TESTS THROUGH 5 1/2-INCH TUBING PRE-CAMBRIAN INTERVAL 11,975-12,045

TEST NO. 2 January 5, 1962

Shut-in Time Minutes	Wellhead Pressure psi	Pressure At 3,000'	Shut-in Time Minutes	Wellhead Pressure psi	Pressure At 3,000'
0	335	1,630	480	29	1,347
1	190		540	25	1,340
5	138		600	20	1,339
10	112		840	12	1,322
15	102	1,401	1080	9	1,314
30	87	1, 388	1, 235	line drained	1, 306
45	80	1, 386	1,295		1,305
60	76	1, 383	1,355		1,303
75	72	1, 381	1,415		1,301
90	68	1, 378	1,475		1,300
120	64	1,371	1,535		1,293
150	60	1,370	1,595		1,290
180	56	1,370	1,655		1,288
210	52	1,370	1,715		1, 287
240	48	1, 368	1,820		1, 285
300	43	1, 363	1,880		1, 282
360	39	1, 353	1,940		1, 279
420	34	1, 352			

Effective Injection Time 682 minutes
Average Injection Rate 208 GPM
Volume of Denver City Water Injected 3, 380 barrels

The bottom-hole pressure was not recorded since the Amerada pressure bomb was dropped in the hole when the wire line broke at 9,000 feet.

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ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL INJECTIVITY TESTS THROUGH 5 1/2-INCH TUBING PRE-CAMBRIAN INTERVAL 11, 975-12, 045'

TEST NO. 3 January 22, 1962

Shut-in Time	Wollhead Pressure psi	Pressure at 7500' psi
0	535	3, 666
l min.	335	3,596
5 min.	270	
10 min.	245	
15 min.	232	
30 min.	210	3,437
l hr.	202	3, 416
2 hrs.	200	3,391
2 hrs. 30 min.		3, 388
3 hrs.		3, 385
4 hrs.		3, 382
6 hrs.		3, 354
8 hrs. 30 min.		3, 353
9 hrs.		3, 290
12 hrs.		3, 211
15 hrs.		3, 186
18 hrs.		3, 174
20 hrs.		3, 171
26 hrs.		3, 164
30 hrs.		3, 161
36 hrs.		3, 158
JU 1111.		-

Effective Injection Time 424 min.
Injection Rates 10 min. at 104 GPM 10 min. at 208 GPM 324 min. at 312 GPM 80 min. at 416 GPM

Volume of Denver City Water Injected 3,450 bbls.

The Amerada pressure bomb was set at 7,500' for safety precautions.

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ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL INJECTIVITY TESTS THROUGH 5 1/2-INCH TUBING PRE-CAMBRIAN INTERVAL 11,975-12,045'

TEST NO. 4 January 25, 1962

Shut-in Time	Wellhead Pressure psi	Pressure At 8,000'	Shut-in Time	Wellhead Pressure psi	Pressure At 8,000'
0	630	3,997	16 hrs.	160	3,642
l min.	380	3,884	18 hrs.	150	3,633
5 min.	335		20 hrs.	141	3,627
15 min.	290		22 hrs.	132	3,618
30 min.	260	3,755	24 hrs.	123	3,608
l hr.	240	3,725	26 hrs.	115	3,605
2 hrs.	230	3,712	28 hrs.	107	3,602
4 hrs.	220	3,691	30 hrs.	99	3, 599
6 hrs.	210	3,688	32 hrs.	91	3,587
8 hrs.	200	3,682	34 hrs.	83	3, 587
10 hrs.	190	3,666	36 hrs.	75	3,587
12 hra.	180	3,663	46 hrs.	35	-
14 hrs.	170	3,660			

Effective Injection Time 373 min.
Injection Rates 59 min. at 196 GPM 314 min. at 392 GPM

Volume of D. City Water Injected 3, 240 bbls.

The Amerada bomb was set at 8,000' for safety precautions.

f A cold White are At A is 12.51

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ROCKY MOUNTAI PRESSURE INJECTION I SUMMARY OF PRESSURE

Date	Operation	∆\' barrels	ΣΛV barrels	Fluid	, fluid	Z _b	Z
9-3- 61	Coring	450	450				1
9-5- 61	DST #13	75	375	Muddy formation water	1.06	9,645	2.
9-6- 61	DST #14	75	300	Formation water	1.05	11,007	
9-8- 61	Injection Test	190	490	Fresh water	1.00		ì
9-10-61	Drilling	477	967				1
9-12-61	Drilling	270	1, 187				1
9-14-61	Drilling	72	1,259				1
9-18-61	Injection Test	401	1,660	Fresh water	1.00	11, 975	
9-19-61	Injection Test	692	2, 352	Fresh water	1,00	11,975	
9-20-61	Injection Test	1,574	3,926	Fresh water	1,00	11,975	1
9-21-61	Ps Test						
9-22-61	Air Lift	-1,100	2,826				}
9-23-61	Air Lift	-7 95	2,031				Ì
9-25-61	Air Lift	-509	1,522				1
10-6-61	Fluid Level						1
10-11-61	Pumping	-79	1,443]
10-12-61	Pumping	-267	1,176				1
10-13-61	Pumping	-188	988				1
10-19-61	Pumping	- 342	646				1
10-20-61	Pumping	-285	361				j
10-21-61	Pumping	-220	121				- 1
10-23-61	Pumping	-424	- 303				1
11-1 -61	Pumping	-185	-488				1
11-3 -61	P . Test						•
11-8 -61	Pumping	-256	-744				3
11-16-61	Pumping	-143	-887				- 1
11-22-61	Pumping	-353	-1,240				1
11-27-61	End Pumping	-202	-1,402				3
12-1 -61	P _s Test	0	-1,402	Formation water		12,000	
12-21-61	P Test		-1,402	Formation water		12,000]
1-3 -62	lnj. Tost #1	4,534	3, 132	Fresh water	1.00	5	12,
1-5 -62	Inj. Test #2	3, 380	6, 180	Fresh water	1.00	3,000	9. ⊈
1-17-62	P Test	0	6, 180	Fresh water	1.00	8,500	3, 4
1-22-62	Inj. Test #3	3, 450	9.630	Fresh water	1.00	7,500	4, 3
1-25-62	Inj. Test #4	3,240	12,870	Fresh water	1.00	8.000	4.0

Y MOUNTAIN ARSENAL DIECTION DISPOSAL WELL PRESSURE TEST RESULTS

7,500

8,000

4,500

4,000

1,949

1,732

			**					
Z _b	$\frac{z_{d}-z_{b}}{ft}$	△P cor	P. psi	pai L+	P _m	Kh md-ft	F.E.	re
9.645 11.007		1,082 459	4,968	4,910 4,694	4, 814 4, 522	431 173	44 87	302 177
11,975 11,975 11,975	25 25 25	11 11 11	4, 943 5, 024					
			4, 359					
			3,040					
2,000 2,000 3,000 8,500 7,500	0 0 12,000 9,000 3,500	0 0 5,196 3,897 1,516	2,125? 2,613 2,714 4,756 4,824	5, 174 5, 244	5, 196 5, 180	3, 390 11, 260	52 53	768 1,522

5,282

5,389

5, 109

5, 291

5,114

5,143

78

68

3, 980

6, 200

6,110

8,700

ROCKY MOUNTAIN ARSENAL PRESSURE INJECTION DISPOSAL WELL CORE DESCRIPTION

Core No. 28

Interval: Pre-Cambrian

Depth: 11,976-11,985'

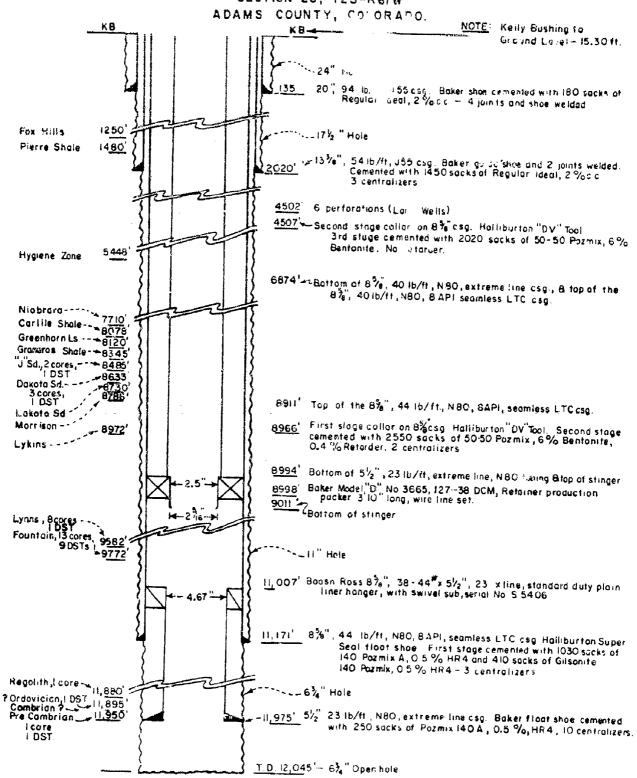
Cut 91: Recovered 6.71

6.01: Biotite, hornblende, granite gneiss, fractured

0.71: Biotite, hornblende, granite gneiss, and pegmatite

CASING AND HOLE DETAILS

PRESSURE INJECTION DISPOSAL WELL ROCKY MOUNTAIN ARSENAL SECTION 26, T25-R67W



A Polumbus Jr And Associates, inc

A

GRAPHICAL REPRESENTATION OF FORMATION EVALUATION DATA ROCKY MUUNTAIN ARBENAL

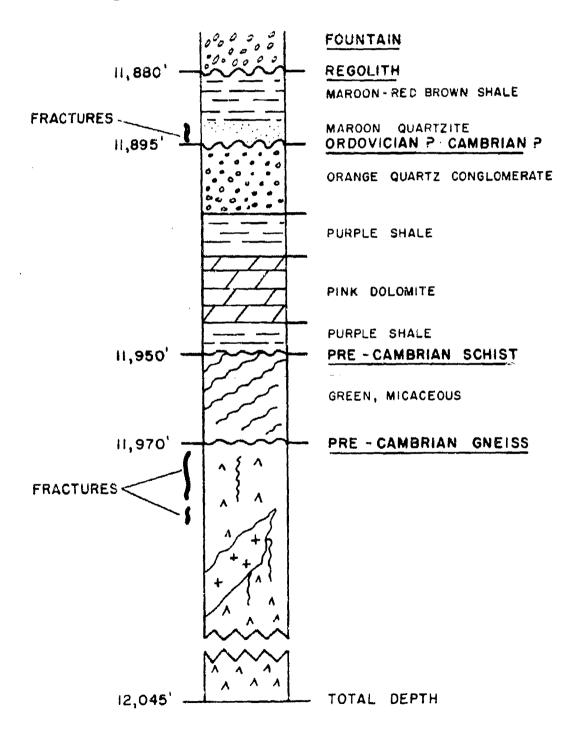
FIG 2

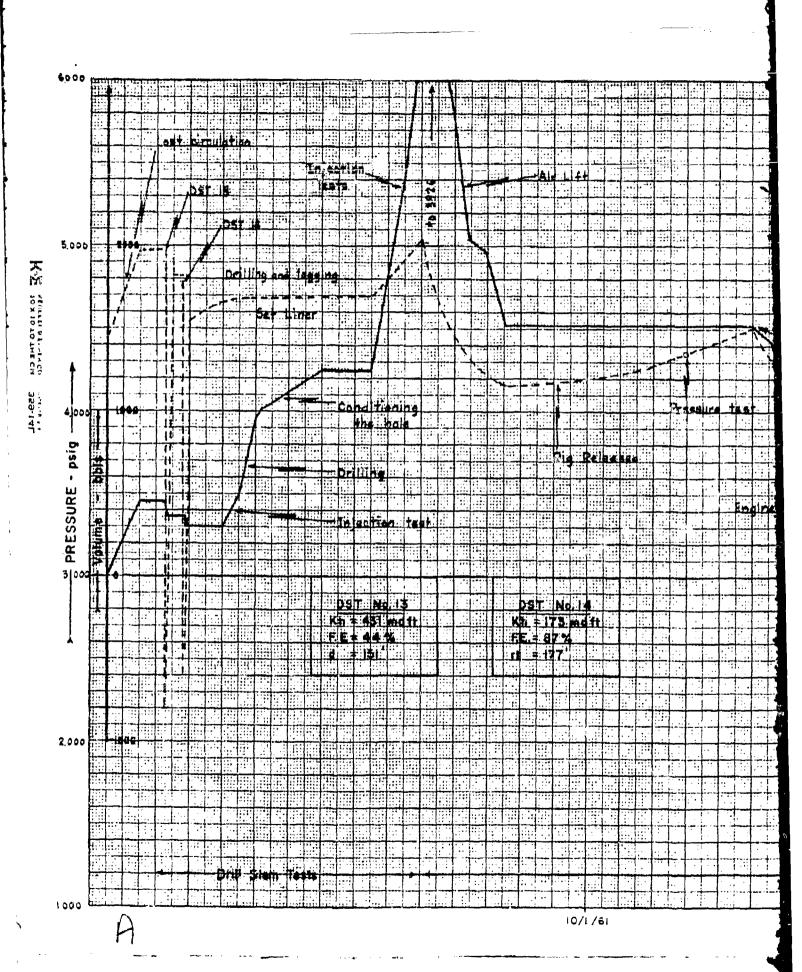
NO 12 INTERVAL 11.780 -- 12,080

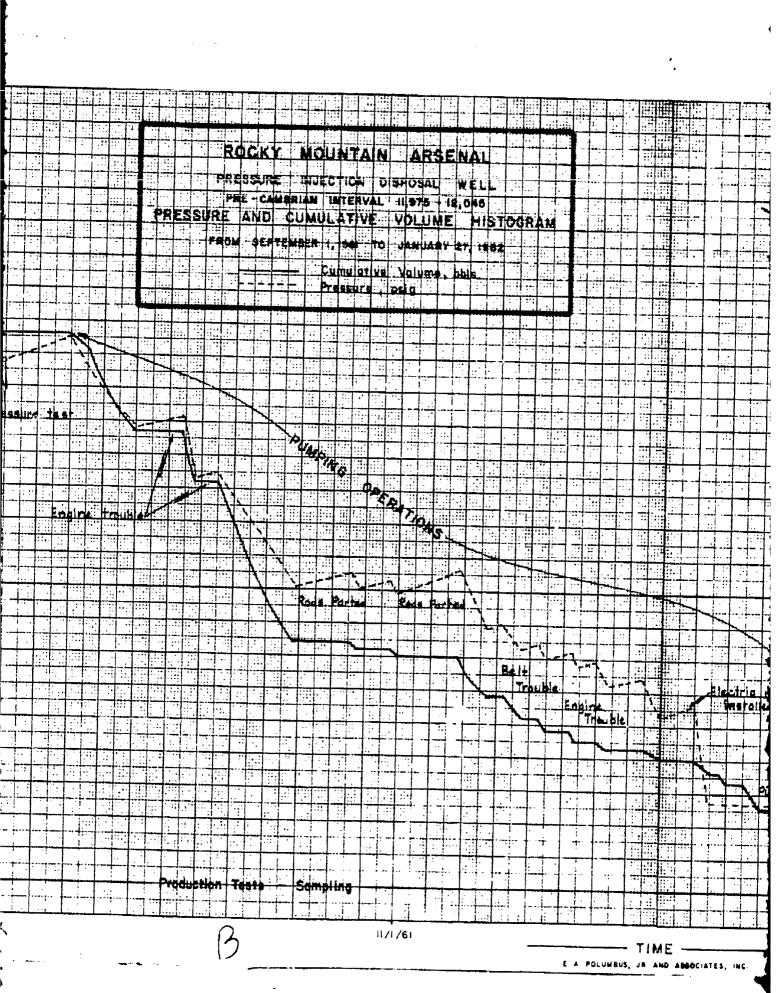
ROCKY MOUNTAIN ARBENAL PRESSURE INJECTION DISPOSAL WELL FRACTURS SHALE OR \$:LTSYONE 42 KOSE Gam Prasters CHALE 27/ROYHMA FRACTURES BAROID BAROID POROSITY PER MEA CORING TIME MINISTES PER POOT DRILLED FORMATICS MARKERS REAMING ORLLING BITE DATE OCCUM-RENCE DHILL STEM TEST RESULTS BEPTH LITHOLOGY DEPTH משדבעונלה באזקשה INDUCTION ELECTRIC LOG BIT 103 D WHERE WARRANTED PACKER AT 4,860 . 14750 11,780 CREEKS SHOK 11, 17 11,020 11.780 11,770 11,770 11,780 U.789 PRESURES D -- II. 19Q (B) 1.790 Hydrostatic Initial Flow 602 3824 2480 3887 hc 4242 Intital Shut BIT 103 D 11,800 Final Shull TIMES: Initial Place whom Initial Shut in 32 min Shut Flow 60 min BECOMERY

2000 W.C. Paris
5333 Mule - 81 Bbls.
NOTE:
Yest Packer set J. 8 5/6
cosing or 96 50 Hote
USBA TO 168 YORK 177 J Loss Cones BIT 104 D BIT 105 D (26) U. 650 Core No 26 11,830 . U.BEO. PRESSURE BIT 10G D FOUNTAIN Tydrostalic Initia: Flow Final Flow Final Bhut la Final Bhut la 4603 1597 3370 4022 · Yemperature 817 107 P No Recovery TIMES 11.860 Initial Flow 11.660 156 min FIRE 90 mia 11,870 RECOVERY - 52 Bels HOTE: Test Pecker set in 6 5/8 "nbeing at it,020" Think aparton 11,560 1001 from 14171 to 11.000 Excessive Pump Pressure WEATHERED SHALE REGOLITH **②** ,... <u>II.</u>, 690 11,895 11,900 11.210 _ מופגנו 31.92C

PRE - FOUNTAIN GEOLOGIC COLUMN







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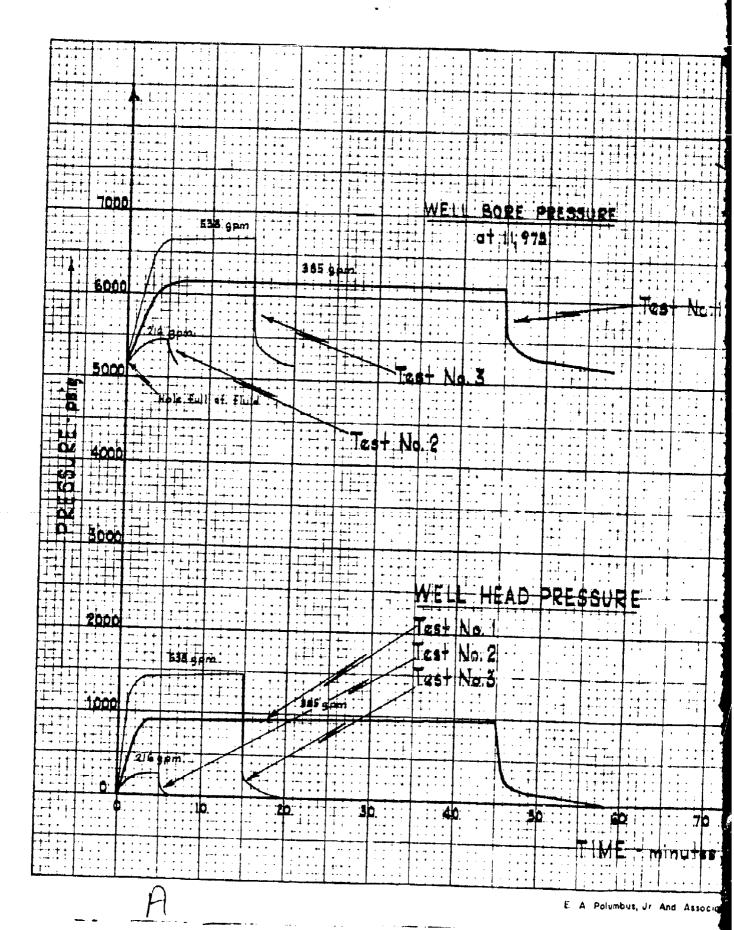
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FIGURE 4

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